ISSN 1027-4510, Journal of Surface Investigation: X-ray, Synchrotron and Neutron Techniques, 2019, Vol. 13, No. 3, pp. 555–561. © Pleiades Publishing, Ltd., 2019.
Russian Text © The Author(s), 2019, published in Poverkhnost', 2019, No. 6, pp. 101–108.

Changes in the Structure and Microhardness of Rapidly Solidified Foils of Aluminum Alloy 1421 during Their Annealing

V. G. Shepelevich[a], I. A. Bushkevich[a], *, E. Wendler[b], and I. I. Tashlykova-Bushkevich[c], **

[a] *Belarusian State University, Minsk, 220050 Belarus*
[b] *Schiller University, Jena, 07743 Germany*
[c] *Belarusian State University of Informatics and Radioelectronics, Minsk, 220013 Belarus*
**e-mail: uyluana@gmail.com*
***e-mail: iya.itb@bsuir.by*

Received June 26, 2018; revised October 12, 2018; accepted October 12, 2018

Abstract—In this work, the relationship between the microstructure and microhardness of Al–Mg–Li–Zr–Sc alloy (1421 Al) prepared by ultrafast quenching from the melt has been studied. The following methods are used in studying the rapidly solidified (RS) alloy: scanning electron microscopy integrated with energy dispersive X-ray microanalysis, the method of nuclear reaction analysis, and the measurement of microhardness changes during isochronal annealing. The intercept method is applied to determine the size of secondary phases, their volume fraction, and the specific surface area of the interface boundaries in the samples. It is established that the as-quenched rapidly solidified alloy foils are composed of an aluminum-based supersaturated solid solution. It is found that lithium, the content of which reaches 9.0 at %, is unevenly distributed over the subsurface region of foils. After annealing at 300°C, precipitates of (Sc, Zr)-containing phase are detected in the structure of foils in addition to magnesium-containing phases. Nonmonotonic changes in the microhardness are observed during isochronal annealing of the foils in the temperature ranges of 50–100°C, 150–210°C, 230–340°C, which are associated with the precipitation of metastable and stable phases. It is found that heating of the alloy foils to 340°C leads to an increase in the microhardness by 23%, and a sharp decrease in the microhardness takes place at temperatures above 400°C.

Keywords: rapid solidification, Al–Mg–Li–Zr–Sc alloy, phase composition, microhardness

DOI: 10.1134/S1027451019030327

INTRODUCTION

The stability of properties during operation is one of the most important requirements for aeronautical engineering materials. Aluminium alloys with an Mg content of less than 7 wt % possess properties that are nearly the same in the annealed, quenched, and aged states. The supersaturated solid solution of magnesium in aluminum is characterized by a relatively high strength and good corrosion resistance together with high plasticity [1]. The effect of strengthening in alloys of the Al–Mg system doped with lithium was discovered in 1965 by academician I.N. Frindlyander [2]. It should be noted for Al–Mg–Li alloys that their strength is comparable to the strength of other aluminium alloys widely used in aviation. On account of the addition of lithium, the alloy density decreases and the elastic modulus increases. At the same time, the specifics of the heat treatment of alloys of the Al–Mg–Li system are associated with the presence of the reinforcing δ' phase (Al_3Li), the decomposition morphology of the supersaturated α-solid solution, the nature of the precipitated additional phases, and their volume-fraction ratio [3]. However, Al–Mg–Li alloys in the coarse-grained state demonstrate limited technological plasticity and low service properties due to strain localization.

Currently, most aluminum alloys are doped with rare-earth and transition-metal additives to enhance their strength and corrosion properties. The effect of the addition of Sc ensures higher strength characteristics in alloys of the Al–Mg system in comparison with the addition of Mn and Zr, which are frequently used as anti-crystallizing agents for aluminium [4–6]. A high radiation resistance of Al–Mg alloys with scandium is reported in [7–9]. The use of Sc together with Zr is also considered to be promising. It is known that only 0.1–0.2 wt % of scandium and zirconium gives rise to a three-fold increase in the strength of aluminium [10]. Zirconium added together with scandium not only replaces a part of expensive scandium, but additionally gives a high strength, weldability, and corrosion resistance to aluminium-based alloys [11], which is especially important in aeronautical engineering.